Mitschunas, Beate; Lenk, Leonhard; Sinzinger, Stefan:

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Zuerst erschienen in: DGaO-Proceedings. - Erlangen-Nürnberg : Dt. Gesellschaft für angewandte Optik. -120 (2019), art. P14, 1 S.

Erstveröffentlichung: 30.08.2019

ISSN: 1614-8436

URN: urn:nbn:de:0287-2019-P014-4

[*Gesehen:* 04.09.2019]

Starting systems for zoom optics with tunable lenses

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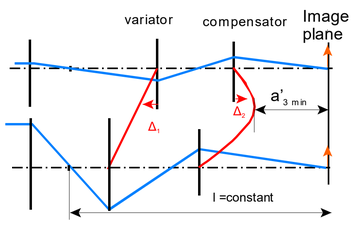
Motivation

Variant 1: Classical zoom system

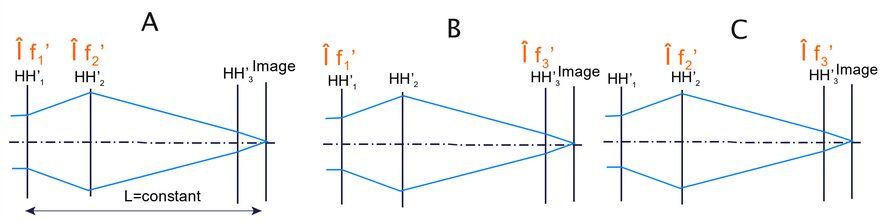
At least two partial optics movable in z-direction. The variator moves linearly and varies the focal length or magnification of the system, and the compensator provides a constant image plane position with nonlinear motion.



Theory for calculating the collinear starting system and for automated parameter selection see / 1 / and / 2 /.

Variant 2: Zoom system with tunable lenses

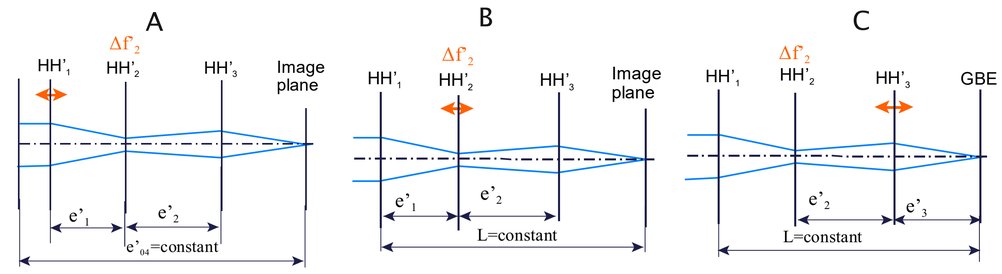
At least 2 tunable lenses from A) tunable lenses with variable radius or B) Alvarez Lohmann lenses



Goal: Variation of the total focal length with a constant length L and without displacements of individual modules in z-direction.

Variant 3: Hybrid zoom system

Combination of tuneable optics with linear displacement of single modules



In total, there are 9 different ways. The variants 3A to 3C are particularly interesting because the tunable lens requires only small diameters.

Which starting system is best for a given task and how can we find it? What are the advantages of tunable lenses in zoomoptics?

Specific example

Step 1: Task for the design of a zoom photo lens

Image Sensor Specifications:

Frame size:	APS-C
Effective area:	23,55mm (H)x15,766mm (V)
Pixel number:	N = 3900 x 2616= 10 202 400
Pixel size:	Δr' = 6.03 µm
Diagonal sensor length:	d = 28.34mm

First order specifications for the 3xZoom lens:

Image height:	y' = 14.17mm
Zoom range :	f' = 17mm bis 51mm
Zoom ratio:	ZR = 3
Half field angle:	w= 39.8° - 15.528°
F-number:	k= 2.8 - 4
Back focal length:	$s'_{F'}$ > 35mm
System length:	L < 175,5mm
Clear aperture of lens:	D< 69,42mm

Evaluation criteria:

Spatial resolution: $MTF \geq 0{,}5\ (\ 42 Lp/mm)$

Distortion: $MTF \geq 0{,}2\ (\ 83 Lp/mm)$

$V \leq 1{,}97\%$

Step 2: Automated parameter selection for a classical zoom lens

Requirements:

f'_A=17mm, ZR=3, k=2,8 - 4,

$2h_{stop\_max}$= 20mm

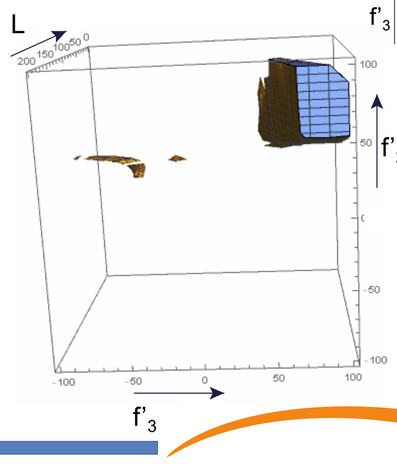
e'_{i_min} = 10mm

f'_{i_min} = 12.5mm

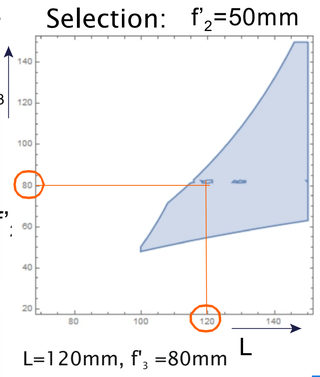
s' > 35mm

The consideration of the distortion condition requires a symmetrically constructed system with the apertur stop in the second lens.

Overview of the parameter space:



Selection: f'_2=50mm



L=120mm, f'_3 =80mm

f'_1 =-30.77mm

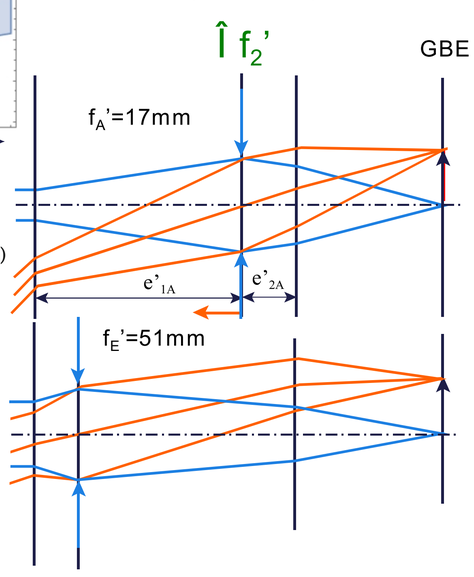
(Compliance with Petzval condition in starting position)

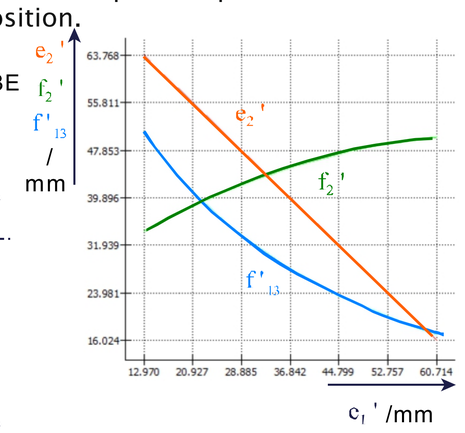
s'=43,362mm

Step 3: Graphical illustration of the system and transformation into a hybrid system using the software PARAX / 3 /.

Initial position of the classical system = initial position of the hybrid system

Replacement of the linear movement of the third partial optics by changing the focal length of the second partial optics while maintaining the image plane position.



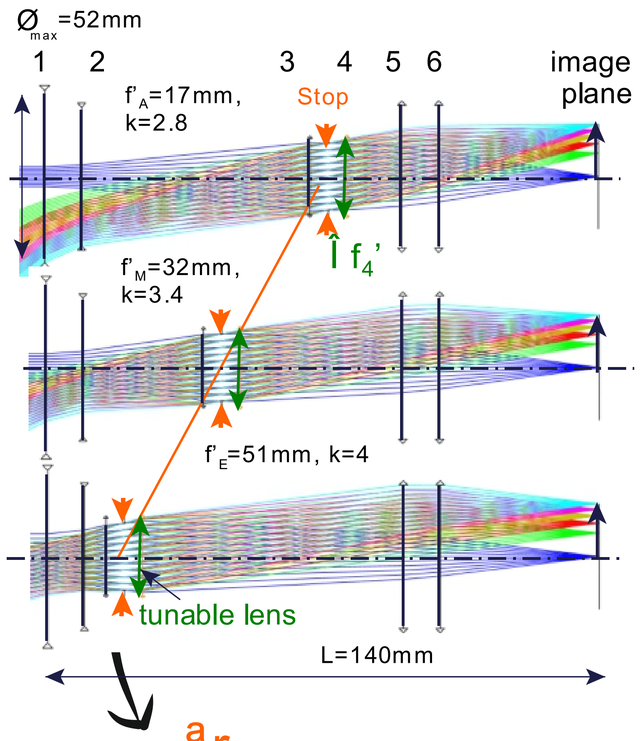


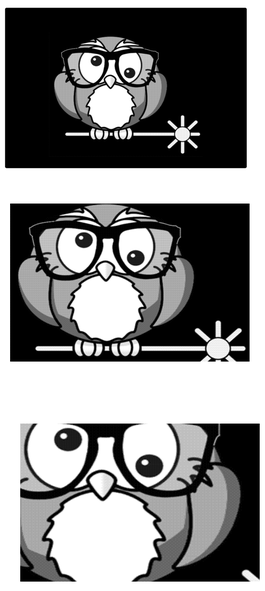
Parameter variation with the software PARAX

Necessary variation of partial focal length:

$$\Delta f_2' = 15.79mm$$

Step 4: Splitting the refractive powers of the partial optics and step by step setup in ZEMAX





Part 2 with the "tunable lens" in the 2nd achromat

Pos	1	2	3	4
f'_{22}/mm 2. Achromat	185,1	113,3	77,2	58
f'_2/mm Part 2	50	44,7	38,9	34,2
tunable radius r/mm	-180	-114	-75,6	-55,9

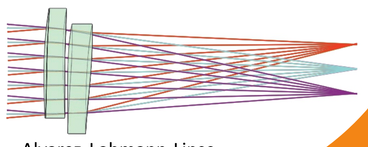
Possible tunable lenses:

A)

[Abb.:Optotune Copyright © 2019]

[Abb.: Holochip Corp.2008]

B)

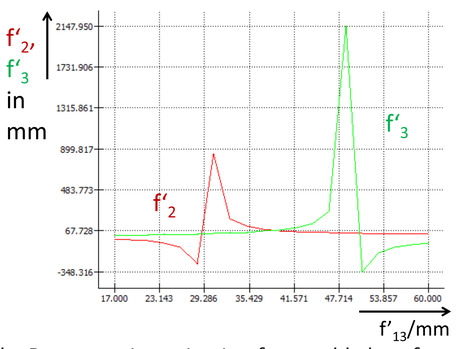


Alvarez-Lohmann-Linse
[Grewe et al., Applied Optics 2014]

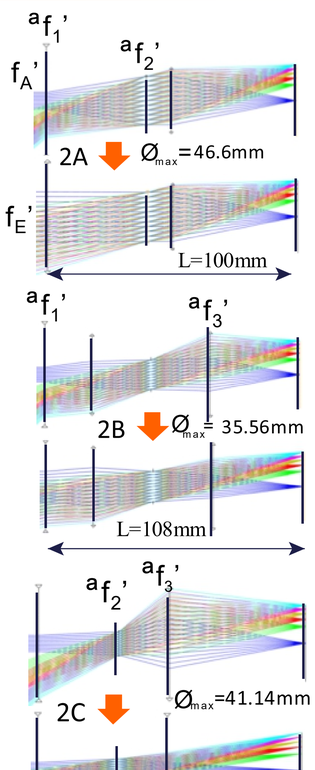
Step 5: Conversion of the hybrid system into a system with only tunable optics and determination of the necessary focal length changes of the partial optics

Parameter variation and parameter iteration

Goal: Determination of the necessary changes to the partial focal lengths



Example: Parameter investigation for tunable lens from variant 2C with the software PARAX



f'/ mm	f'1/ mm	f'2/ mm	k
17	-20.6	60.6	2,8
28.5	-53	93	
40	-160	200	
51	2040	-2000	

f'/ mm	f'1/ mm	f' 2 /mm	k
17	-24.2	33.4	2,8
28.5	-41.7	41.4	3,2
40	-60.3	54.7	3,6
51	-79.2	78.8	4,1

f'/mm	f'2/ mm	f'3/ mm	k
17	-20.9	21.2	2,8
28.5	-303.4	33.1	4,6
40	63	75.4	6,4
51	38.8	-339.1	8,3

Zoom system with tunable lenses:

Advantage:
Smaller dimensions in length and diameter and no movements in z-direction!

Disadvantage:
Larger focal length variations and larger diameters of "tunable lenses" required!
A) Large radius changes necessary!
B) The challenge is the optimization of freeform surfaces!

Final step: Comparison of the investigated possibilities and selection of an optimal starting system for the simulation and optimization with ZEMAX

System variant	1	2A	2B	2C	3A	3B	3C
Maximum diameter of the system and system length	-	++	++	++	-	+	-
Change of F-number	+	-	+	--	+	+	+
Change of partial focal length	x	-	-	-	++	++	++
Clear aperur of tunable lenses	x	-	-	-	++	++	++

Legend:

++ especially advantageous
+ advantageous
- disadvantageous
-- not practicable

Variant 3B (hybrid) is the best starting system for the chosen task!
The final hybrid system design of the ZEMAX simulation meets all requirements, is shorter and has a smaller diameter than the classic zoom system introduced in / 4 /.

Literature

[1] L. Lenk, B.Mitschunas, S.Sinzinger: Zoom lenses with tunable lenses and linear lens movements. Paper presented at EOSAM 2018, Delft, 8-12 October 2018.
[2] L. Lenk, B.Mitschunas, S. Sinzinger: Zoom systems with tuneable lenses and linear lens movements, JEOS - Rapid Publications-D-19-00011R1, 2019
[3] B. Mitschunas,B. Rudolf, R. Bielert, J. Mitschunas: Kollineare Modellierung komplexer optischer Systeme, Photonik 2.2016, S 46-49
[4] W.-S. Sun, P.-Y. Chu, C.-L. Tien and M.F. Chung,„Zoom lens design for 10.2- megapixel APS-C digital SLR cameras, Vol 56, No. 3, Applied Optics, 2017

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DGaO-Proceedings 2019 - http://www.dgao-proceedings.de - ISSN: 1614-8436 - urn:nbn:de:0287-2019-P014-4
submitted: 02.07.2019 published: 30.08.2019